CHAPTER 5
MONETARY VALUATION OF HEALTH EFFECTS CHANGES

5.1 INTRODUCTION

This chapter presents monetary value estimates for the adverse human health effects expected to be reduced because of the reduction in ambient sulfate aerosol concentrations attributable to Title IV. Monetary value estimates are presented for an average case of each type of health effect quantified in this assessment.[1] These monetary value estimates per case are multiplied by the estimated reduction in number of cases to obtain total monetary value estimates for each type of health effect. These are then summed to total monetary value estimates for all health effects benefits attributable to the sulfate aerosol reduction.

5.1.1 Monetary Valuation Concepts for Health Effects

The purpose of this assessment is to quantify the benefit to society of the reduction in health effects expected from the Title IV required SO_2 emissions reductions. Monetary values for changes in risks of human health effects should therefore reflect the full consequences to the affected individuals and to society.

Adverse health effects result in a number of economic and social consequences, including:

1. **Medical costs**. These include personal out-of-pocket expenses of the affected individual (or family), plus costs paid by insurance or medicare, for example.

2. **Work loss**. This includes lost personal income, plus lost productivity whether the individual is compensated for the time or not. For example, some individuals may perceive no income loss because they got sick pay, but sick pay is a cost of business and reflects lost productivity.

3. **Increased costs for chores and caregiving**. These include special caregiving and services that are not reflected in medical costs. These costs may occur because some health effects reduce the affected individual's ability to undertake some or all normal chores, and he or she may require caregiving.

[1] This chapter relies on previous literature reviews prepared for EPA including Violette and Chestnut (1983), Chestnut and Violette (1984), and Fisher et al. (1989).

4. **Other social and economic costs**. These include restrictions on or reduced enjoyment of desired leisure activities, discomfort or inconvenience (pain and suffering), anxiety about the future, and concern and inconvenience to family members and others.

Cost-of-illness (COI) measures include only medical costs plus work loss (Consequences 1 and 2 above), and thus do not reflect the total welfare impact of an adverse health effect. Therefore, using COI measures in a quantitative assessment results in a clear downward bias in the valuation of adverse health effects. COI measures, however, have the practical advantages of being easily understood and often readily available because they are based on available market and expenditure data.

A comprehensive monetary measure of value for changes in health risk is the dollar amount that would cause the affected individual to be indifferent to experiencing an increase in the risk of the health effect or losing income equal to that dollar amount. This monetary measure is the maximum willingness to pay (WTP) to reduce the risk of the health effect and all associated costs. WTP will thus reflect all the reasons an individual might want to avoid an adverse health effect, including financial and nonfinancial concerns.[2] WTP is a more comprehensive measure of value than COI, but it can be more difficult to estimate.

Sometimes in this discussion of monetary valuation for health effects we distinguish between health effects and health risks. A health effect refers to an illness or symptom, including death, that is experienced by someone. A health risk is the quantitative probability that any one individual might experience a given health effect. Changes in air quality cause changes in the number of health effects in the exposed population, but from the point of view of the individual what changes is the risk of experiencing a given health effect. This is because it is unknown exactly which individuals might be affected. WTP estimation techniques for more serious health effects such as premature mortality or chronic illness tend to focus on changes in the risks of such health effects that an individual might experience. For example, WTP studies for premature mortality do not estimate what individuals would be willing to pay to prevent a certain death, but rather estimate what they are willing to pay for small changes in risks of death.

5.1.2 WTP Estimation Techniques for Health Risks

WTP is typically measured by analyzing prices that are paid for goods and services. The maximum price that an individual is willing to pay for a good or service is a measure of how much they value that good or service. Prices cannot be directly observed for preventing health risks because

2 Financial costs of health effects are not always borne fully by the individual but are shared through health insurance and public health care subsidies. In some instances therefore empirical estimates of WTP to avoid or reduce health effects may not fully reflect these shared costs. For a comprehensive measure of WTP such shared costs should be added to individual WTP.

prevention of health risks is not directly purchased in the market. However, there are instances when the monetary tradeoffs that people are willing to make between income and health risks can be observed or measured. There are two general economic approaches for measuring WTP for nonmarket goods such as health risk prevention. The first is to analyze actual situations in which WTP for health risks may be indirectly revealed; the second is to have subjects respond to a hypothetical situation designed to have them reveal their WTP.[3]

An example of the first approach is a wage-risk study in which wage premiums for risks of death on the job are estimated. This is done by analyzing all the factors that determine differences in actual wages between jobs, including on-the-job risks of death. The amount of additional wages that people are paid per unit of additional risk of fatal injury is a measure of the monetary value of that risk to the individual who voluntarily accepts that risk in exchange for a given wage increment. The primary advantage of this type of study is that it is based on actual behavior. The primary limitations are that it is difficult to find situations in which there is a clear tradeoff between money and risk, and to statistically isolate WTP for a risk increment from other factors involved in the specific behavior.

An example of the second approach is a contingent valuation study in which subjects are presented with a hypothetical situation that involves a tradeoff between income or expenditures and a specific health risk or health effect. The subjects are then asked to estimate what they would be willing to pay to change that risk by a specific amount. It is important that the hypothetical situation presented to study subjects be realistic and easy to understand. The primary concern with this type of study is whether subjects are able to give accurate responses to hypothetical questions.[4]

5.2 ISSUES IN APPLYING WTP ESTIMATES FOR THIS ASSESSMENT

Although WTP for changes in health risks is the conceptually correct monetary value measure for this assessment, there are some limitations in available estimates. These limitations result from uncertainties in the available estimates, inexact matches between the health risks for which WTP estimates are available and the health risks of interest in this assessment, and the lack of available WTP estimates for some of the health risks of interest.

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[3] This section provides a brief introduction to these estimation techniques. For more information see Freeman (1993).

[4] Contingent valuation is a somewhat more controversial technique than some other economic valuation techniques. There are only a few instances when we are relying entirely on estimates from contingent valuation studies for monetary valuation estimates for specific health effects in this report. Snell et al. (1993) review the contingent valuation studies used in this report in light of recent recommended contingent valuation guidelines.

WTP estimates are available for risks of death, but there are some differences between the types of fatal risks for which WTP estimates are available and those of interest in this assessment. WTP estimates are also available for some but not all types of morbidity of concern in this assessment.

5.2.1 Issues in Applying Available WTP Estimates for Premature Mortality

There are several uncertainties in applying the available WTP estimates for valuing changes in premature mortality risks. The justification for using the available WTP estimates is that they provide estimates of what people are willing to pay to reduce their risks of premature mortality by small amounts. The risks involved in this analysis are also small, but there are some differences with regard to who is at risk and what the risk is. First, there is quantitative evidence from the health effects literature that a large share of the individuals at risk are elderly (65 years old or older). Two additional aspects of potential significance are the potential health status of the people at greatest risk and differences regarding the expected cause of death. There is very little available empirical evidence about how these factors might affect the value of reducing risks of premature mortality. There is, therefore, some unresolved uncertainty in applying available WTP estimates in this analysis.

Age

Available evidence of the effect of age on WTP for changes in mortality risks is discussed in Section 5.3. The empirical evidence is quite limited, but it provides a basis for some adjustment in average WTP estimates for elderly individuals for changes in mortality risks. Most available WTP estimates for changes in mortality risks, however, are from studies in which the elderly are not well-represented. The adjustment selected for the elderly in this analysis, therefore, must be acknowledged as relatively uncertain. The adjustment for age explained in Section 5.3 is based on an analysis of the available empirical evidence first presented by Rowe et al. (in press). Other approaches for addressing the age question could be justified, including making no adjustment; however, we selected the approach proposed by Rowe et al. as a reasonable interpretation of limited empirical evidence.

Health Status

The available WTP estimates for changes in mortality risks are based on results from study samples of individuals with average levels of health. Although it cannot be determined from available epidemiologic studies, it is possible that those individuals at greatest risk of premature mortality due to exposure to air pollutants are those who are already in poor health for reasons unrelated to air pollution exposure. Some instances may involve chronic illnesses, because of which the individual may already have a reduced life expectancy even in the absence of pollution exposure. For example, Schwartz and Dockery (1992a) found increased mortality rates due to chronic respiratory disease, pneumonia, and cardiovascular disease associated with higher levels of particulate matter. Some of these individuals apparently suffer from preexisting chronic disease. There is not sufficient evidence available to say how having a chronic illness might affect WTP for changes in mortality risks, but it is possible that the reduced life expectancy and irreversibly reduced quality of life associated with many chronic illnesses may result in lower WTP to reduce mortality risks.

Cause of Death

It is possible that people are more concerned about avoiding some kinds of death than others. For example, Jones-Lee et al. (1985) results suggest that some people are more afraid of death from cancer than of death from automobile accidents. This may be related to the perceived pain, suffering, and expense associated with the illness that precedes death in the case of cancer. Some studies also suggest that people find involuntary risks, such as pollution exposure, less acceptable than voluntary risks, such as traffic accidents (Violette and Chestnut, 1983). Studies have not been able to separate these different aspects of the different risks of death in terms of the potential effect on WTP. The most reliable WTP studies to date have focused on accidental deaths, primarily on the job and in vehicle accidents. The types of death of interest for this analysis are related to various illnesses, both chronic and acute. Based on the limited evidence available about how people respond to different types of risks, it is likely that if there is any error in applying available WTP estimates in this analysis it will be to understate the WTP to avoid the types of risks of interest in this analysis.

For this analysis, available WTP estimates for changes in risks of death are applied to all estimated mortality risks regardless of the cause of death. Although arguments could be made for small adjustments in some cases, any such adjustment is overshadowed by the level of uncertainty in using these estimates, which cannot be reduced at this time. For example, WTP estimates based on accidental death probably do not reflect the medical costs typically associated with treatment of the chronic or acute illness that may precede premature death due to air pollutant exposure. However, COI estimates suggest that average lifetime medical costs per chronic respiratory disease patient are under $100,000 (Krupnick and Cropper, 1989). This omission is not very significant relative to a selected range of WTP estimates of $2 million to $7 million per fatality.

5.2.2 WTP to COI Ratios

WTP estimates are not available for some of the nonfatal health effects considered in this analysis. In these cases, COI estimates are used and are adjusted upward by a factor of 2 to compensate for the expected ratio of WTP to COI estimates for any given health effect. This adjustment is based on limited available evidence on WTP/COI ratios, but we believe the resulting adjusted health valuation estimates are less biased than would occur if only unadjusted COI estimates were used. This section develops a general WTP/COI ratio to escalate COI values to approximate WTP values. Because this ratio is likely to be specific to each health effect, any such ratio based on existing studies must be seen as an approximation to improve valuation and reduce known bias that would occur if unadjusted COI estimates were used to value health effects.

This summary of the empirical evidence and the selected ratio for adjusting the COI estimates is taken from Rowe et al. (in press). The empirical literature on this question is limited and other interpretations could be justified, including making no adjustment at this time. Our judgment was that an uncertain adjustment was preferable to no adjustment, because no adjustment results in a clear downward bias in the estimates.

Three studies provide evidence on WTP/COI ratios for the same study population addressing the same change in the same health effect. In each study, the participants were individuals diagnosed with the health effect. These studies addressed changes in incidence of asthma symptoms (Rowe et al., 1984; Rowe and Chestnut, 1986), increased angina symptoms (Chestnut et al., 1988), and risks of cataracts (Rowe and Neithercut, 1987). In each study, participants rated the importance of each of the components of WTP (listed in Section 5.1.1), and provided WTP estimates for reducing or preventing these health effects. The participants rated some non-COI consequences as more important to avoid than the COI consequences. This again suggests that WTP significantly exceeds COI.

The dollar ratio results listed in Table 5-1 are based on estimated individual and social COI in dollars, and on individual WTP in dollars. Individual COI is less than social COI because society incurs some costs the individual does not (because of insurance coverage, sick pay, and other types of compensation). Because social COI exceeds individual COI, the WTP/COI ratio for individuals exceeds the ratio for society. Also available from the asthma and cataract studies are respondent ratings of their COI as a share of their perceived total damages. From these ratings, the individual and society WTP/COI ratios are computed and reported in Table 5-1.

Across the three studies, the total social WTP/COI ratios range from 1.3 to 2.4. The COI in these studies range from a few dollars to $7,000 per episode of cataracts. Based on these results, we select a WTP/COI ratio of 2.0 for this analysis. Thus, we multiply available COI estimates by 2.0 to approximate WTP, when actual WTP estimates are not available for a given health effect.

Basing a WTP/COI adjustment on these study results is admittedly uncertain. The study samples are small and the range of health effects is limited. However, we still judge that it is preferable to make some adjustment than to make no adjustment. Making no adjustment in COI estimates for valuation purposes results in a clear downward bias. We have selected a fairly conservative adjustment factor, based on available evidence, to minimize the chance of overadjusting. Additional evidence that these adjustment factors are conservative exists in the WTP estimates for risks of death. Average COI estimates for fatalities are typically in the

Table 5-1
WTP/COI Ratios

Health Effect		WTP/COI Affected Individual	WTP/COI Society
Asthma Symptoms	Dollar ratio	1.6 to 2.3	1.3 to 1.7
Cataracts	Dollar ratio	4.25	2.4
	Respondent rated share of total damages ratio	5.3	2.1
Angina Symptoms	Respondent rated share of total damages ratio	2.5-4	NA

Sources: Asthma: Rowe et al. (1984), Rowe and Chestnut (1986).
Cataracts: Rowe and Neithercut (1987).
Angina: Chestnut et al. (1988).

middle hundreds of thousands. WTP estimates per fatality are in the millions, a difference of an order of magnitude.

5.3 MONETARY VALUATION ESTIMATES FOR PREMATURE MORTALITY RISKS

Several economic studies have estimated average WTP in the United States for small changes in risks of accidental death. These estimates have been widely used in benefit analysis of public policy options that would result in changes in risks of death for the public (Viscusi, 1992). They are sometimes referred to as "value of life" estimates because they are expressed on a per life basis. But it is important to note that they are based on WTP of the individual for reducing his or her risk of premature death by a small amount, not on the total value of a human life under all circumstances.

The estimates provided by these studies are average dollar amounts that individuals are willing to pay for small reductions in risks of death. For example, one study might find an average WTP of $300 for an annual reduction in risk of death of 1 in 10,000. These estimates are extrapolated to a per life basis by summing individuals' WTP over enough people that a value per life saved is obtained. In this example, this value would be $3 million per life, the result of $300 multiplied by 10,000 people. The term used for this estimate in much of the economics literature is "value of a statistical life" (VSL) to denote that it is a summation of WTP for small changes in risks of premature death.

Available estimates of WTP to prevent small changes in risks of death are based on situations where individuals are observed making tradeoffs between probabilities of death and some benefit, such as income. Most of these studies have estimated wage premiums associated with different levels of on-the-job risks. Additionally, some contingent valuation studies have been conducted in which subjects have been asked what they would be willing to pay to reduce, for example, their risks of fatal accidents at work or in traffic accidents. A few averting behavior studies have also been conducted that estimate costs associated with observed behaviors that reduce risks, such as smoke detector usage in the home or seat belt usage in automobiles.

For the most part, available WTP estimates are for risks of accidental death in circumstances where individuals are voluntarily exposed to risks (e.g., choosing a job or driving in a car). The estimates are also drawn largely from studies of working-age adults. Some potentially important differences exist between the contexts of these available estimates and the environmental health risks being evaluated in the externality model. Environmental health risks are related to illness rather than accidents and may in some cases fall disproportionately on the elderly and those with already compromised health. The potential implications of these differences were discussed in Section 5.2.1. The potential effect of age on WTP is discussed in more detail in Section 5.3.2.

5.3.1 Summary of Available WTP Estimates

Four recent reviews of this literature evaluated and summarized available WTP estimates for small changes in risks of death for potential use in analyses of public policy decisions (Fisher et al., 1989; Miller, 1989; Cropper and Freeman, 1991; Viscusi, 1992). Each review concludes with a list or range of “best” estimates that the authors judged as most appropriate for use in evaluating public policy decisions that result in small changes in risks of death for the public. All of these reviews covered basically the same body of literature, but the most recent review (Viscusi, 1992) included a few additional studies that were not completed when the earlier reviews were done. These reviews are consistent in many of their conclusions regarding which of the available estimates are most appropriate for use in policy analysis, but there are also differences. We take into consideration the conclusions, and their basis, of each of these four reviews in selecting a central, low, and high estimate of WTP for changes in risks of death for use in this analysis. The selected estimates for this analysis are discussed in Section 5.3.3. Ranges of VSL recommended by the authors of each of the four reviews as best for policy analysis are listed in Table 5-2.

Fisher et al. (1989) list 21 studies that each give a VSL estimate. The authors reject three studies listed as “early low-range wage-risk estimates,” primarily because of problems in the risk data used. The authors also reject the “consumer market studies,” which fall into the category of averting behavior studies, because they argue that each of the estimates is clearly downward biased because of study design problems or data limitations. They also reject one of the “new wage-risk studies” that examined wages for police officers in the United States, because of the limited scope of the study sample and potential problems with the on-the-job death rate data used.

Table 5-2
Recommended Ranges of VSL Estimates

Review	VSL Rounded to Millions (1994 dollars)	
	Low	High
Fisher et al. (1989)	$2	$11
Cropper and Freeman (1991)	$2	$7
Viscusi (1992)	$3	$8
Miller (1989)	$1	$4

This leaves 13 VSL estimates judged by these authors as most appropriate for use in policy analysis. These estimates range from $2 million to $11 million (1994 dollars), and have an arithmetic mean of about $6 million. All but two of the 13 studies are wage-risk studies. The remaining two studies are contingent valuation studies, which obtained results of $4.1 million and $3.8 million. These results fall in the lower half of the overall range. Fisher et al. caution that all the estimates above $8 million are based on wage-risk studies using Bureau of Labor Statistics data for on-the-job risks. These data are limited in that they give risk information by industry, but not by occupation. There is no specific reason why these data would cause any upward bias in VSL results, but results that are not verified by similar conclusions using different data sources are somewhat less robust. The authors therefore conclude that the $2 million to $8 million range is the strongest because it has been verified by different studies using varying data sources, but they do not rule out the possibility that the higher estimates might be correct.

Cropper and Freeman (1991) present an adapted version of Table 1 from Fisher et al. They deleted four of the 21 studies. The authors do not explain these exclusions, but presumably they found them to be less appropriate for policy analysis than the remaining 17. Two of the deleted studies were in categories that were rejected by both sets of reviewers, so their exclusion causes no change in the conclusions. The primary difference in the conclusions of these two reviews is that Cropper and Freeman make a stronger statement that using the Bureau of Labor Statistics on-the-job risk data apparently causes upward bias in the VSL estimates, based on comparisons of results using different types of data. Excluding the estimates based on Bureau of Labor Statistics data leaves six VSL estimates judged as “best” for use in policy analysis. These are from four wage-risk studies and two contingent valuation studies. The wage-risk estimates selected by Cropper and Freeman range from $2.1 million to $7.3 million (1994 dollars), and the contingent valuation estimates selected range from $3.5 million to $4.1 million. The arithmetic mean of all six selected VSL estimates is $4.1 million.

Viscusi (1992) provides separate discussions and summaries of averting behavior, wage-risk, and contingent valuation studies. His overall conclusion is that the most appropriate range of VSL estimates for use in policy analysis is $3 million to $8 million in 1994 dollars. He also rejects the available averting behavior study results for use in policy analysis because of clear downward biases in the study designs and data. Viscusi lists 27 VSL estimates from 22 wage-risk studies and eight estimates from six contingent valuation studies. Similar to the conclusions of the previous reviewers, Viscusi raises questions about some of the earlier wage-risk studies that used inappropriate risk data and obtained relatively low VSL results. He also raises some questions about some of the wage-risk studies that obtained results above $8 million. Viscusi concludes that the best VSL results from wage-risk studies are between $3 million and $8 million. Viscusi suggests that the two earliest contingent valuation studies were exploratory and that less weight be given to these two estimates (one is very low, the other is very high). The arithmetic mean of the remaining four contingent valuation estimates is either $3.1 million or $5.1 million, depending on whether the median or the mean estimate is selected from one of the studies. The range of the contingent valuation estimates is $1.4 million to $4.3 million or $11.0 million, depending on whether the median or the mean value is selected from one of the studies.

Miller (1989) uses a different approach than that used in the other three reviews and reaches some different conclusions. He selects a larger number of available VSL estimates as potentially appropriate for use in policy analysis, but makes several adjustments in the estimates to reconcile differences in study design or limitations in data. Miller includes 29 VSL estimates as of "reasonably good quality." Included in these 29 estimates are most of the estimates selected in the other reviews as most appropriate for policy analysis. An important difference is that Miller includes results from eight averting behavior studies, which are rejected by the other reviewers as likely to be biased downward. An additional four are from contingent valuation studies, and the remaining 17 are wage-risk estimates. Miller made several adjustments to the estimates, most of which resulted in lowering the estimates, especially for some of the wage-risk studies with the highest results. The adjustments Miller made included (1) converting the wage-risk results to after-tax dollars, (2) adjusting for differences in labor risk data sources, (3) adjusting for failure to include nonfatal injury risks in the analysis, (4) adjusting to a uniform value of time or discount rate if used, and (5) adjusting for differences in perceived versus actual risks. The conceptual arguments for some of these adjustments may be valid, but the reliability of the data used to determine the exact adjustment to make is in many cases questionable. Miller concludes by choosing a mean VSL estimate of $2.7 million (1994 dollars), and a range of $1.4 million to $4.3 million.

5.3.2 The Potential Effect of Age on WTP for Changes in Mortality Risks

Although it has been suspected that age may be a factor in risk of death due to air pollution exposure, until recently there has been little quantitative evidence in the available epidemiologic literature. Schwartz and Dockery (1992a) report evidence that the measured association between daily mortality rates and daily levels of ambient particulate matter is greater for people over the age of 65. They provide sufficient information to estimate the change in the number of deaths expected for people over 65 and under 65 for a given change in ambient particulate matter. It is therefore important to consider whether average WTP for changes in mortality risks might be different for people over 65.

This raises the question of whether WTP for changes in risks of death in the current time period is different for people over 65 than for the average adult. There is limited empirical evidence regarding this question, but some information is available. The expectation is that WTP will be lower for a 65-year-old than for the average adult, because expected remaining years of life are fewer. This expectation is based on the presumption that WTP for one's own safety is derived from the utility one receives from one's own life and that this utility is to some extent a function of the amount of time one expects to remain alive.

Some analysts have suggested that effects of age might be introduced by dividing average WTP per statistical life by average expected years of life remaining (either discounted or not) to obtain WTP per year of life (Miller, 1989; Harrison and Nichols, 1990). Such a calculation implies very strong assumptions about the relationship between life expectancy and the utility a person derives from life, namely, that utility is a linear function of life expectancy. Although this might be correct, it is also plausible that this calculation will result in significant understatement of WTP for the elderly. An understatement could result for a number of reasons. One is that there may be a value to being alive that is independent of the amount of time one expects to live. Another is that as one ages, the remaining time may be more highly valued than it was in midlife.

We have identified one study that provides unconstrained empirical evidence concerning how WTP for small changes in risks of death varies with age. Jones-Lee et al. (1985) conducted a contingent valuation study concerning motor vehicle accidents and report an estimated WTP function for characteristics of the respondents, including age.[5] (There are some other studies that provide some suggestive evidence regarding how WTP for reducing risks may change with age, but each of these studies imposes some constraints on the conclusions in the form of unverified model assumptions.)

Jones-Lee et al. conducted a general population survey in the United Kingdom in which about 1,000 respondents were asked how much additional money they would be willing to pay for transportation with a bus company with a better safety record. All relevant risk information was quantitatively specified and the survey appears to have been well designed and executed. Implied WTP per life (VSL) was calculated for each response. For example, the VSL is $6 million when the WTP response is $240 for a reduction in risk of death of 4 in 100,000. Variations in the implied VSL estimates across respondents were then examined as a function of age and other

5 This summary and proposed adjustment in the monetary values based on available empirical evidence of the effect of age on WTP for changes in mortality risks is drawn from Rowe et al. (in press).

characteristics of the respondents. An appropriate functional form was used that allowed WTP to be a nonlinear function of age (age + age^2).

The results show a statistically significant relationship estimated between age and VSL, which was statistically strongest for the responses to the first bus safety questions. The results indicate gradually increasing VSL until around age 45, then gradually declining VSL. The results for both the bus safety questions imply that VSL for a person aged 65, all other things being equal, is about 90 percent of VSL for a person aged 40.

The Jones-Lee et al. results with respect to age, based on the responses to the first bus safety question, are:

$$\text{VSL} = \text{Constant} + 12{,}489 \times (\text{Age} - \text{Mean Age}) - 660 \times (\text{Age} - \text{Mean Age})^2 + zB_iX_i, \quad (5\text{-}1)$$

where:

VSL	=	the implicit VSL given by the respondent
B_iX_i	=	the other independent variables in the WTP regression.

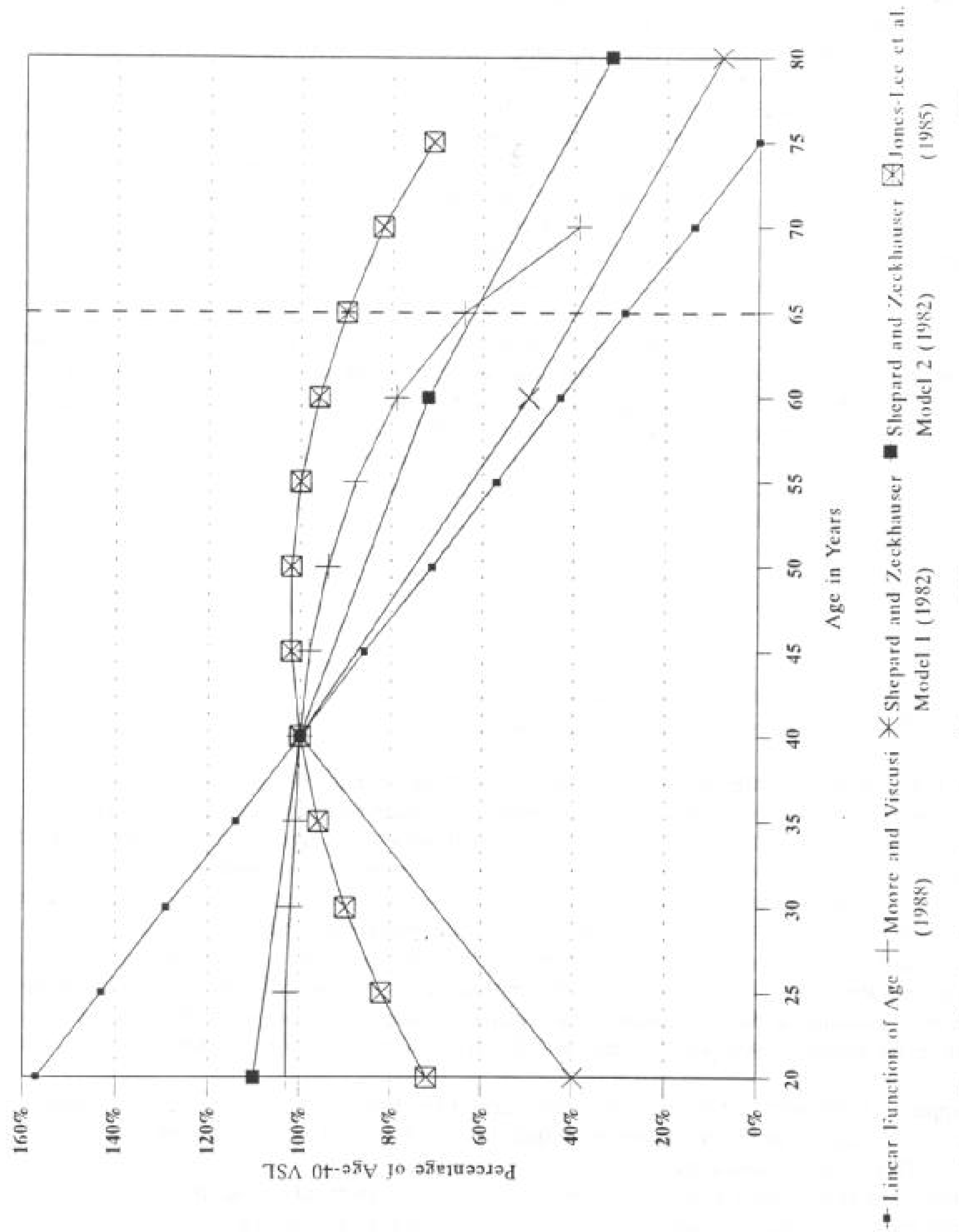
The authors do not report mean age for the sample, but describe the sample as nationally representative. For purposes of interpreting the regression results, we use 40 years as an average age, which is close to the average age of adults in the United States. The average VSL is reported as 1.6 million British pounds. We then calculated illustrative VSL estimates at selected ages using the following formula:

$$\text{VSL} = 1{,}600{,}000 + 12{,}489 \times (\text{Age} - 40) - 660 \times (\text{Age} - 40)^2. \quad (5\text{-}2)$$

This calculation assumes that other factors that influence VSL do not change with age. The risk of error due to this assumption seems small because only the age variables were statistically significant in this regression.

To allow for simple comparison to the results of other studies, we calculated VSL at each age using Equation 5-2. We then calculated VSL at each age as a percentage of VSL at age 40. These percentages are plotted in Figure 5-1.

Figure 5-1
Value of a Statistical Life as a Function of Age



Moore and Viscusi (1988) estimated a wage-risk premium for a sample of workers in the United States. They defined risk on the job as the probability of a fatal accident multiplied by the discounted remaining life years of the individual. They used a nonlinear estimation technique to estimate both the risk coefficient and the implicit discount rate for time. They also included an expected annual annuity variable to account for the possibility that a wage-risk premium might not be as high if available insurance covers some of the risk to dependents. The results showed a significant relationship between wages and risks of fatal accidents and implied a value per statistical life of about $6.5 million (1986 dollars). The finding of a significant (negative) relationship between wages and expected annual annuity suggests that estimates that ignore potential death benefits may understate WTP to reduce risks of death. The estimated discount rate was 10 percent to 12 percent.

The Moore and Viscusi model assumes a constant value per year of life, and future years are discounted at rate *r*. The model, therefore, does not provide an unconstrained test of how VSL varies with age. VSL at different ages is simply a function of the discount rate, according to this model, and is therefore proportional to discounted remaining life years. The model implies that WTP for small changes in current risks decreases with age throughout a person's lifetime. How fast it declines depends on the discount rate. Moore and Viscusi define discounted remaining life years as:

$$\mathrm{DRLY} = 1/r \times [1 - \exp(-r \times \mathrm{R})] \qquad (5\text{-}3)$$

where:

DRLY = discounted remaining life years
R = expected life years remaining.

The implications of different discount rates on WTP for changes in risks of death can be illustrated as follows. VSL will be proportional to the discounted remaining life years (DRLY). This means that the ratio of VSL at age 40 to VSL at age 65 will be the same as the ratio of DRLY at age 40 and DRLY at age 65. The implications of Moore and Viscusi's results from their linear wage function (r = 9.6 percent) with respect to the age of the worker are shown in Figure 5-1. It should be noted that the estimates are based on a sample of 317 working adults, which included few individuals over age 60 (62 is two standard deviations above the mean age). Also, life expectancies do not actually decline linearly with age, as is assumed in the calculations that underlie Figure 5-1. Average life expectancy at birth in the United States was 75 years in 1983, but was 17 years for 65-year-olds.

Cropper and Freeman (1991) provide a summary of the life-cycle consumption-saving model that can be used to derive a theoretical definition of WTP for changes in the probability of death. This model is based on the premise that utility is a function of consumption. The authors note that if there is additional utility derived from survival per se, then the life-cycle model provides a lower bound estimate of WTP. Of interest is what the model predicts in terms of how WTP for changes in risks of death in the current time period changes as a function of age. For a quantitative example, this depends on assumptions regarding a lifetime pattern of earnings, endowed wealth, the rate of individual time preference, and other parameters of the model. These will all vary for different individuals, and uncertainty exists empirically about population averages for many of these factors. However, using reasonable values to calibrate the model is illustrative.

Cropper and Freeman (1991) note that if consumption is constrained by income early in life, the model predicts that VSL increases with age until age 40 to 45, and declines thereafter. Shepard and Zeckhauser (1982) illustrate this point with numerical examples for the life-cycle model. When they estimate the model with reasonably realistic parameters and assume no ability to borrow against future earnings or to purchase insurance, they find a distinct hump in the VSL function that has a peak at about 40 years and drops to about 50 percent of the peak by 60 years. When they allow more ability to borrow against future earnings and to purchase insurance, the function flattens and at 60 years drops only to 72 percent of the VSL at age 40.

For comparison purposes, all of the estimates discussed above are plotted in Figure 5-1 along with the relationship between VSL and age implied by a simple linear decline with age. This linear decline implies that VSL at age 65 is about 30 percent of VSL at age 40. This is a much larger decline in VSL as a function of age than implied by the available empirical results reported above. The strongest weight should be given to the Jones-Lee et al. results because they are based on a representative general population survey and were not unduly constrained by an imposed functional form. However, survey results can be highly variable and need to be interpreted cautiously until verifying results from multiple studies are obtained.

The life-cycle model results are quite variable depending on assumptions used to quantify the model. These assumptions have not been verified empirically. Because the model defines utility as a function of consumption and consumption is a function of time, it is expected that if the life-cycle estimates err it is on the side of overstating the effect of age on VSL (in other words, reducing VSL too much at age 65 relative to age 40). The error would result if there is some value to just being alive independent of consumption. At consumption levels above subsistence, this is quite plausible. Therefore, these estimates should be interpreted as representing the maximum plausible reductions in VSL as a function of age.

5.3.3 Monetary Estimates Selected for this Analysis

Obviously, there is some judgment involved in selecting central, high, and low values for the WTP for changes in risks of death. The selected mortality valuation estimates for each age group are summarized in Table 5-3. We selected $4.5 million as the central estimate, $2.5 million as the low, and $9.0 million as the high for those under 65. The central estimate of $4.5 million is consistent with the mean ($4.1 million) of the six estimates indicated by

Table 5-3
Summary of Selected Monetary Values for Mortality Effects

Population Group	VSL Estimate (1994 dollars)		
	Low	Central	High
>65 years	$1.9 million	$3.4 million	$6.8 million
<65 years	$2.5 million	$4.5 million	$9.0 million
Age Weighted Average	$2.0 million	$3.5 million	$7.1 million
Selected Probability Weights	33%	50%	17%

Cropper and Freeman as most appropriate for policy analysis uses. It is within the range of results from both wage-risk and contingent valuation estimates, and is consistent with giving less weight to the wage-risk studies that have relied on Bureau of Labor Statistics risk data. When these are included, the mean estimate from the Fisher et al. review is $6.3 million. In selecting the central estimate we have given less weight to the Miller review because of the uncertainties involved in many of the adjustments he made in the estimates. Both the study selection and the adjustments made by Miller suggest that his conclusions are on the low side in terms of an appropriate VSL estimate for policy analysis. The central estimate of $4.5 million is close to the upper end of the range selected by Miller as appropriate for policy analysis. The low estimate selected for those under 65 is just below Miller's mean VSL estimate of $2.7 million. It is the lower end of the range selected by Fisher et al. and Cropper and Freeman. The selected high estimate falls within the upper estimates of $11 million and $7 million from the first three reviews summarized above. The VSL estimates discussed in Section 5.3.1 are based primarily on samples of working age adults. A few of the contingent valuation studies included individuals of retirement age, but this age is not well represented in the mean VSL values. We therefore apply the selected VSL estimates from these studies to the under 65 years old population.

Available evidence suggests that WTP for small changes in risks of death for people over age 65 can be expected to be lower than WTP for the same change in risk at age 40. However, there is considerable uncertainty about how much lower. The most relevant direct evidence suggests that the decline in VSL with age may be relatively small (e.g., 90 percent of the age 40 WTP at age 65). The evidence strongly suggests that a linear decline in VSL with age significantly understates actual VSL over age 65. Based on our evaluation of the above described evidence regarding VSL and age, we utilize the Jones-Lee et al. results to calculate a weighted average VSL based on the approximate age distribution for the U.S. population age 65 and older. This produces an adjustment to VSL for those 65 years old and older of about 75 percent of the average VSL for adults under age 65. Taking 75 percent of the estimates per statistical life selected above for adults under 65, we get a central estimate of $3.4 million for those over 65, a low of $1.9 million, and a high of $6.8 million.

A age-weighted average VSL for this analysis is then calculated on the assumption that 85 percent of the sulfate-related deaths are people aged 65 and over (See Chapter 4). The results are shown in Table 5-3. These are the VSL estimates applied to the predicted changes in premature deaths associated with Title IV in this assessment.

The selection of probability weights for the low, central, and high estimates is somewhat arbitrary because there are several uncertainties in using these estimates in this analysis for which no quantitative information is available. The selected weights therefore reflect the uncertainty in the underlying WTP estimates for small changes in risks of accidental death for working-age adults, but do not fully reflect the uncertainty in applying these estimates in this analysis. The weight selected for the central estimate is 50 percent, because the underlying WTP estimates are predominately in the $3 to $6 million range. A weight of 33 percent is given to the low estimate and a weight of 17 percent to the high. This reflects that the high estimate is represented by fewer studies and a somewhat skewed distribution in the available WTP estimates. These weights result in a weighted mean value that approximates the selected central estimate.

5.4 MONETARY VALUATION ESTIMATES FOR MORBIDITY

WTP estimates of value are available for about half of the nonfatal health effects identified in Chapter 4, primarily the least serious health effects. However, most of the WTP studies completed to date have limitations because of small sample sizes and limited variation in the health effect studied, and few of these studies have been replicated. Some interpretations and adjustments in the results of the WTP studies have been necessary in applying them for this analysis. These studies have been reviewed and synthesized in previous air quality benefits studies (Rowe et al., in press; Krupnick and Kopp, 1988; Hall et al., 1989; Thayer, 1991; Unsworth and Neumann, 1993). We rely to a large extent on these previous reviews for specific interpretations.

When WTP estimates are not available at all, the monetary estimates are based on COI information, and the COI values are inflated to WTP estimates, as discussed in Section 5.2. The COI information used in this analysis reflects medical costs and lost productivity due to illness. The average daily wage is used as a measure of lost productivity for days when all normal activities are prevented because of illness. Such days include days spent in the hospital, one day for each emergency room visit, and days spent in bed because of illness. The average wage rate is used as a measure of the average opportunity cost of time for employed and not-employed individuals, on the presumption that those who are not employed value their leisure or household services at a level equal to the wage they forego in choosing not to pursue paid employment. This approach may somewhat overstate foregone wages for the elderly and women, who make up a large share of the not-employed group and may have less than average earning power in the labor market. On the other hand, this approach does not reflect any productivity losses beyond the average work-day hours, thereby understating productivity losses for employed and not-employed individuals who perform household, childcare, and community service work beyond the usual work-day hours. This omission, however, is offset by the adjustment used to proxy WTP when using the COI estimates. For these calculations, we use the 1994 median daily wage for full-time salaried workers in the United States, which is about $93 (U.S. Dept. of Labor, 1995).

The available WTP studies provide some information on the range as well as the mean WTP values. In general, these ranges are minus 50 percent to plus 50 to 100 percent. A range of plus or minus 50 percent is therefore applied to the central estimates of WTP based on COI data in this analysis to derive the low and high estimates. High and low values are selected from the range of WTP results available when WTP studies have been conducted for those health endpoints. The low, central, and high WTP estimates for all morbidity effects are given equal probability weights. This reflects the limited number of empirical studies providing the WTP estimates and the fairly extensive assumptions and approximations used in deriving all of the estimates.

5.4.1 Adult Chronic Bronchitis

Viscusi et al. (1991) and Krupnick and Cropper (1992) conducted a set of survey exercises to estimate WTP for reducing risks of developing chronic respiratory disease. In both studies, respondents were presented with trade-off options for risks of developing chronic bronchitis (or chronic respiratory disease in general) versus cost of living. Respondents were presented with hypothetical residence location options where in some locations risks of developing chronic respiratory disease are lower but cost of living is higher. An additional trade-off question was for risks of developing chronic bronchitis versus risks of death in an auto accident. An interactive computer program was used to adjust the trade-off until the respondent reached a point of indifference between the two options. At this point, a maximum WTP to prevent developing chronic bronchitis is revealed.

The health endpoint defined in these studies does not exactly match that defined in the Abbey et al. (1995) study, upon which the estimates of new cases of chronic bronchitis are based (see Chapter 4). The primary difference is the level of severity. The WTP studies defined a severe case of chronic bronchitis. The Abbey et al. results reflect a more average case. In this section we present the results of these WTP studies and a procedure for adjusting the results to better reflect the level of severity of interest for this analysis.[6]

The samples for the two studies differ. Viscusi et al. selected a representative sample of about 390 respondents. Krupnick and Cropper selected a sample of individuals who had a relative with a

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[6] This adjustment procedure is based on information reported by Krupnick and Cropper (1992) and was suggested by Alan Krupnick in personal communication.

chronic respiratory disease. The Krupnick and Cropper sample was smaller (about 190 respondents) and less representative of the general population (lower average age and higher average income), reflecting a large percentage of respondents taken from the University of Maryland staff and students. The intent of the Krupnick and Cropper study was to test for the effect of familiarity with the disease on WTP responses.

Both studies used a definition of chronic bronchitis that reflects a severe case. The description of the disease included persistent symptoms of cough and phlegm, limits in physical activities, and ongoing medical care. Krupnick and Cropper used this definition in one version, and asked respondents to consider the risk of developing “a case of chronic respiratory disease like your relative’s” in a second version. The relatives had chronic bronchitis, asthma, or emphysema. Respondents provided information on the severity of the relative’s disease based on the number of symptoms present. This ranged from 0 to 13, where 13 reflects the severe chronic bronchitis case defined in the earlier questions. The analysis of WTP responses included the effect of the severity of the relative’s case on the WTP response. At the mean of the variables, the estimated elasticity of WTP with respect to severity was 1.16. This means that WTP increased by 1.16 percent for every 1 percent increase in the 0 to 13 symptoms scale.

The WTP results from Viscusi et al. are more appropriate for this assessment because they are from a study sample that is more representative of the general population. The responses reflect the maximum amount the respondents revealed they would be willing to pay to reduce their annual risk of developing chronic bronchitis by a specified amount. The authors then calculated the implicit WTP per statistical case avoided. The median response for the cost of living trade-off was approximately $570,000, and the arithmetic mean was about $1,100,000 in 1994 dollars. The authors caution that the mean is affected by a small number of fairly high estimates and recommend that the median is more representative of the sample. We cautiously accept this recommendation until the accuracy of the high estimates can be further verified in repeated studies and analyses. For a low estimate for a severe case of chronic bronchitis we select the 20th percentile value of $340,000 and for a high estimate we select the 80th percentile value of $900,000.

We use an elasticity estimate for numbers of symptoms to scale the estimates for a severe chronic bronchitis case to better reflect WTP to avoid a more typical case. The elasticity estimate is calculated from results reported by Krupnick and Cropper for a combined analysis of chronic bronchitis, asthma, and emphysema. Using this estimate for chronic bronchitis assumes that the elasticity of WTP with respect to severity is similar for chronic bronchitis to that for all three diseases combined. The mean severity rating reported for the Krupnick and Cropper sample is 6.5, based on the 0 to 13 scale. Using the elasticity at the mean of 1.16, this suggests that WTP for an average case is 58 percent lower than for a case at 13 on the scale. Using this to adjust the Viscusi et al. estimates, we get a central WTP estimate of $240,000, a low of $140,000, and a high of $380,000 for an average chronic bronchitis case.

It is important to note that these WTP estimates for preventing a new case of chronic bronchitis reflect the perceived welfare effects of living with chronic bronchitis over the entire course of the illness, which can span many years. It is a measure of the present value of the welfare effect that occurs over a multiple-year period. This is somewhat different than the other morbidity effects considered in this analysis which are short-term effects. In using the WTP values for chronic bronchitis we are assigning the full welfare effect for the new chronic bronchitis case in the year in which the clinical onset of the disease occurs. We do the same with the acute morbidity effects, but in those cases the illness typically begins and ends in the same year.

5.4.2 Respiratory Hospital Admissions

WTP estimates for respiratory hospital admissions (RHA) are not available. We therefore use the COI approach. The American Hospital Association reports an average cost per day of a hospital stay of $820 in 1992 dollars (as cited in U.S. Bureau of the Census, 1994). This is inflated to $920 (1994 dollars) using the medical consumer price index. We calculated the average length of stay in the hospital for the 13 ICD-9-CM codes[7] in the Burnett et al. (1995) study (see Chapter 4) using data from the 1992 National Hospital Discharge Survey (Graves, 1994). We found an average length of stay for a respiratory hospital admission of about 6.8 days, which is slightly longer than the overall average length of stay in the hospital for all conditions of approximately 6.2 days (Graves, 1994). The length of stay is multiplied by the average cost per day as an estimate of the medical cost of a RHA. The length of stay is multiplied by the average daily wage (W) as an estimate of the value of lost productivity for employed and not- employed individuals on the presumption that it is a measure of average opportunity costs for all individuals. The medical cost and lost productivity estimates are summed and multiplied by the WTP/COI ratio of 2 to account for additional potential pain and suffering and activity losses not reflected in the COI numbers. The central estimate is thus calculated as follows:

$$\text{Central \$/RHA} = (6.8 \times 910) + (6.8 \times W) \times WTP/COI. \tag{5-4}$$

Therefore, the central estimate is $14,000 (1994 dollars), rounded to the nearest thousand. Applying a plus or minus 50 percent adjustment results in a low estimate of $7,000 and a high estimate of $21,000.

[7] The ICD-9-CM codes included were: 466, 480, 481, 482, 483, 485, 486, 490, 491, 492, 493, 494, and 496. The diseases they correspond to include acute bronchitis, chronic bronchitis, pneumonia, emphysema, and asthma.

5.4.3 Cardiac Hospital Admissions

WTP estimates for cardiac hospital admissions (CHA) are not available. We therefore use the COI approach. The American Hospital Association reports an average cost per day of a hospital stay of $820 in 1992 dollars (as cited in U.S. Bureau of the Census, 1994). This is inflated to $920 (1994 dollars) using the medical consumer price index. We calculated the average length of stay in the hospital for the 4 ICD-9-CM codes[8] in the Burnett et al. (1995) study (see Chapter 4) using data from the 1992 National Hospital Discharge Survey (Graves, 1994). We found an average length of stay for a cardiac hospital admission of about 6.9 days, which is slightly longer than the overall average length of stay in the hospital for all conditions of approximately 6.2 days (Graves, 1994). The length of stay is multiplied by the average cost per day as an estimate of the medical cost of a CHA. The length of stay is multiplied by the average daily wage (W) as an estimate of the value of lost productivity for employed and not- employed individuals on the presumption that it is a measure of average opportunity costs for all individuals. The medical cost and lost productivity estimates are summed and multiplied by the WTP/COI ratio of 2 to account for additional potential pain and suffering and activity losses not reflected in the COI numbers. The central estimate is thus calculated as follows:

$$\text{Central \$/CHA} = (6.9 \times 910) + (6.9 \times W) \times \text{WTP/COI}. \tag{5-5}$$

Therefore, the central estimate is $14,000 (1994 dollars), rounded to the nearest thousand. Applying a plus or minus 50 percent adjustment results in a low estimate of $7,000 and a high estimate of $21,000.

5.4.4 Restricted Activity Days

A restricted activity day (RAD) is a measure of illness defined by the Health Interview Survey (HIS) as a day on which illness prevents an individual from engaging in some or all of his or her usual activities. This includes days spent in bed, days missed from work, and days with minor activity restrictions because of illness. WTP estimates for preventing a RAD are not available. We therefore approximate WTP for an average RAD using available COI data and WTP estimates for days with symptoms.

RADs reflect a combination of complete activity restrictions and minor activity restrictions. It is unknown what proportion of RADs attributable to air pollution exposure is minor rather than severe. Recent data from the HIS indicate that about 40 percent of all RADs are bed-disability

[8] The ICD-9-CM codes included were: 410, 413, 427, and 428. The diseases they correspond to are acute myocardial infection, angina pectoris, cardiac dysrhythmias, and heart failure.

days.[9] The results of Ostro (1987) suggest that RADs associated with air pollution exposure may be less severe on average than all RADs. We therefore presume a lower proportion of bed-disability days for this analysis than the national average for all RADs. We select an assumption that 20 percent of RADs due to air pollution exposure are bed-disability days.

WTP studies do provide some information about values for preventing illness symptoms that are probably associated with minor restricted activity days (MRADs). There are no studies specifically addressing the WTP to avoid an MRAD; however, Loehman et al. (1979), Tolley et al. (1986), and Berger et al. (1987) report results from survey respondents who were asked how much they would be willing to pay to avoid a day with various specified symptoms such as serious or minor coughing. The focus of these studies was on respiratory symptoms that might be related to air pollution levels, but the results from each of these studies are difficult to interpret for this analysis because there is fairly wide variability in the responses and because the definitions of symptoms vary. However, Krupnick and Kopp (1988) note that an MRAD is probably more severe than a single minor symptom day (congestion, cough, etc.); hence, they concentrate on the WTP estimates for severe symptoms in Loehman et al. and symptom combinations in Tolley et al. For a central estimate, they select $26 (1994 dollars), which is Loehman's high median value for a severe symptom day.

Productivity losses associated with more serious RADs (bed-disability days) are estimated as equivalent to the daily wage rate for employed individuals. We apply the same measure of lost productivity for not-employed individuals on the presumption that it is a measure of average opportunity costs for all individuals. This lost productivity estimate is multiplied by the WTP/COI ratio of 2 to account for additional potential pain and suffering, additional leisure activity losses, and potential medical costs that are not reflected in the lost productivity estimates. Taking a weighted average of the value for more serious and more minor RADs gives the average value for an air pollution induced RAD as follows:

$$\text{Central \$/RAD} = [0.20 \times W \times WTP/COI] + [0.80 \times 26]. \qquad (5\text{-}7)$$

Therefore, the central estimate is $60 (rounded to the nearest ten). Applying a plus or minus 50 percent adjustment results in a low estimate of $30 and a high estimate of $90.

5.4.5 Asthma Symptom Days

Krupnick and Kopp (1988) review two studies that provide monetary value estimates for asthma symptom days. The first is a study by Krupnick (1986), which presents the medical expenditures associated with ozone-induced asthma attacks. The expenses vary by the baseline number of

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9 National Center for Health Statistics (1992) reports average number of restricted activity days for all adults in the United States in 1991 was 16.1, and the average number of bed-disability days was 6.5.

attacks and by the assumed prices for medical services. Krupnick and Kopp use these figures as a benchmark for calibrating estimates of WTP.

The second study (Rowe and Chestnut, 1986) is a WTP survey study that obtained asthmatics' estimates of WTP to prevent an increase in "bad asthma days" (BADs). Each respondent defined for himself a BAD on a 1 to 7 severity scale for asthma symptoms. After analyzing the WTP responses, Rowe and Chestnut found WTP estimates that are about 1.8 times greater than the medical costs found by Krupnick. Krupnick and Kopp point out that this finding is consistent with economic logic and lends credibility to both studies. Thus, for WTP values to prevent an asthma attack, Krupnick and Kopp rely on the Rowe and Chestnut estimates.

Rowe and Chestnut found that the WTP responses were positively associated with the baseline number of annual attacks. The values also varied by how an asthmatic defined a BAD. For example, when a BAD was defined as a day with any symptoms, the WTP estimate was $13 in 1994 dollars. At the higher end of the scale, when a BAD was defined as a day with more than moderate symptoms, the WTP was $58. A central estimate is $36. We follow Krupnick and Kopp and adopt these WTP estimates.

5.4.6 Lower Respiratory Symptom Days

Krupnick et al. (1990) estimated the number of study subjects who reported any respiratory symptoms on a given day as a function of air pollutant levels on that day. These included 19 specific symptoms such as coughing, congestion, and throat irritation. The symptoms were noticeable to the subjects, but did not necessarily result in any changes in the person's activities on that day. This health effect therefore includes but is not limited to restricted activity days. In the procedures used to add the health effects cases, restricted activity days are subtracted from acute respiratory symptom days because of the overlap in the definitions of these health effects. The monetary valuation required for acute respiratory days is therefore a value for the days on which symptoms are noticeable but do not restrict normal activities for that day.

Loehman et al. (1979) and Tolley et al. (1986) obtained estimates of WTP to avoid a day with a single minor respiratory symptom such as head congestion or coughing. Their median results per day in 1994 dollars range from $6 to $17. We prefer the median results from these studies because neither study did any adjusting for potentially inaccurate high WTP responses, resulting in reported mean WTP estimates that far exceed the median values. The medians may be too low relative to the average WTP that we would prefer to use in this analysis, but there is less risk of significant upward bias in the median estimates from these studies. We prefer to err in this direction. We select $11 as typical of the range of estimates obtained in these two studies for minor respiratory symptoms. We select a low of $6 and a high of $17.

5.4.7 Summary of Selected Morbidity Values

Table 5-4 provides a summary of the selected monetary values for human morbidity effects.

Table 5-4
Summary of Selected Monetary Values for Morbidity Effects

Morbidity Effect	Estimate per Incident (1994$)			Primary Source	Type of Estimate[1]
	Low	Central	High		
Adult chronic bronchitis	$140,000	$240,000	$380,000	Viscusi et al. (1991) Krupnick and Cropper (1992)	WTP
Respiratory hospital admission	$7,000	$14,000	$21,000	Equation (5-4) Graves (1994)	Adjusted COI
Cardiac hospital admission	$7,000	$14,000	$21,000	Equation (5-5) Graves (1994)	Adjusted COI
Restricted activity day	$30	$60	$90	Equation (5-7) Loehman et al. (1979)	WTP & Adjusted COI
Asthma symptom day	$13	$36	$58	Rowe and Chestnut (1986)	WTP
Lower respiratory symptom day	$6	$11	$17	Loehman et al. (1979) Tolley et al. (1986)	WTP
Selected probability weights for all effects	33%	34%	33%		

[1] WTP = Contingent valuation WTP estimate.
Adjusted COI = COI × 2 to approximate WTP.